AIRBAG EFFICIENCY IN FRONTAL REAL WORLD ACCIDENTS

Jean-François HUERE
Jean-Yves FORET-BRUNO
Gérard FAVERJON
Jean- Yves LE COZ
Laboratory of Accidentology, Biomechanics and human behaviour
FRANCE

Paper number: 2001-S1-O-193

ABSTRACT

The analysis of accidents studied by LAB shows that, among injured belted drivers involved in frontal crashes, in cars **without airbags**, head injury risk is the highest along with lower limbs 's one.
The LAB investigation of severe accidents, involving new car models, regularly carried out all over the French territory, has given the opportunity to analyse head injury risks for about 300 belted drivers in crashes with airbags. The average severity of these accidents was in the range of EuroNCAP tests.(between 36 and 65 km/h EES)
The present paper's purpose is to compare the risk of head injury for belted drivers **with and without airbag**. Other body area injury risk, like neck and upper limbs, has also been considered.
These severe accidents analysis shows high airbag efficiency in reducing severe facial and brain injuries.

METHOD

In order to get clear outcomes on the frontal airbag efficiency, it has been decided to deal only with driver's airbags where the number of cases is large enough due to its earlier implementation compared to passenger's side.
More than 300 drivers having experienced a severe frontal crash with the airbag deployed have been compared with more than 500 drivers in cars without airbags in comparable crashes.
The cars without airbag being the reference sample has been selected from early 90's conception cars and later to limit stiffness biases, and all comparisons made by EES classes.
Global severity has been checked for both samples and then detailed by body regions. Obviously, head AIS1+, AIS 2+ and 3+ injuries have been compared as well as neck and upper limbs ones. The clavicle injuries have been removed from the upper limbs because we believe that they are mainly due to shoulder belt interactions more than airbag deployment.
The detailed head injury type remaining have been then considered.

SAMPLE DESCRIPTION

This study is based on in depth accident studies run by LAB for several years. LAB's teams usually investigate accidents according to two different areas. The first one is a district located west from Paris including urban and rural road network (we will call this area "zone"). In this area, all the road accidents with at least one injury are in depth investigated, daily, with all car make and models and no special other criterion. This accidents sample is not strictly representative from the national French situation but many special studies have shown that it is not so far.
The other investigation area is the whole French national territory on the rural police network (French Gendarmerie) where LAB's engineers select severe accidents based on specific criteria like make, model, type of restraint system or special crash configurations. These so-called "targeted" cases allow getting immediate feedback on the effect of recent countermeasures like airbags or belts with force limiters. It is then possible to observe these effects without waiting for a certain renewal of the cars on the road.

The sample selection criteria are:
- Frontal impact excluding underride.
- Belted drivers.
- 11-01 o'clock impact direction.
- All types of impacted objects.
- All overlaps.
- All crash severities.

Figure 1 describes the sample speed distribution in both investigation areas: Zone and Targeted.

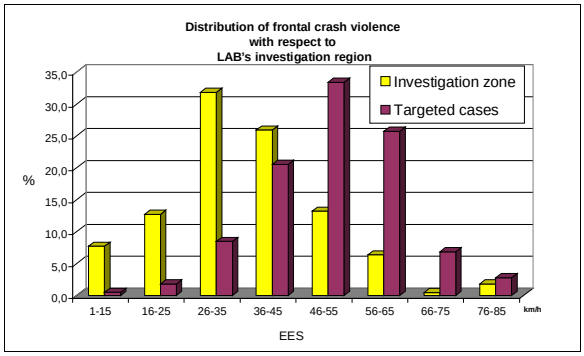

Figure 1

This figure shows the important proportion of high speed and severe accidents in the Targeted sample compared to the other. This means that in average this study will deal with severe accidents

The most important part of airbag cases was obviously collected from the targeted sample because it is one of the first priority selection criteria.

In order to avoid stiffness biases as much as possible, we selected the reference sample from accidents involving cars designed from and after 1989. This reference sample was then made up of cars which are not equipped with driver air-bag but recent enough compared to the airbag equipped cars sample. Figure 2 provides information on the work sample and the final 834 drivers chosen for this study.

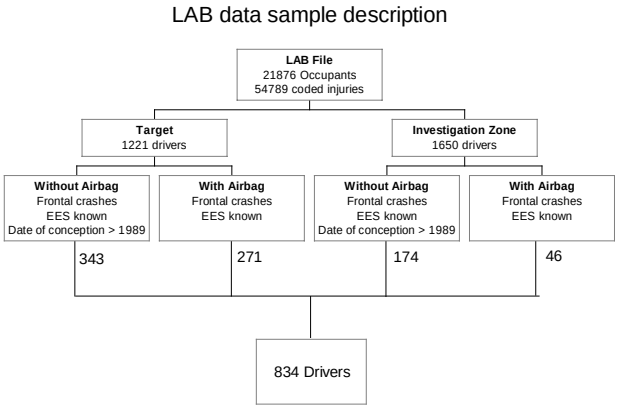

Figure 2

These 834 drivers are distributed in two sub samples:

- Cars with driver airbag deployed = 317
- Cars with no airbag = 517

MAIS	0	1	2	3	4	5	Killed
Without AB	69	143	162	72	22	9	40
With AB	41	94	95	56	8	2	21

Table 1

The directions of the occupant trajectories in the two sets of data were fairly comparable and essentially frontal (12h or 0°±15°). (Figure 3).

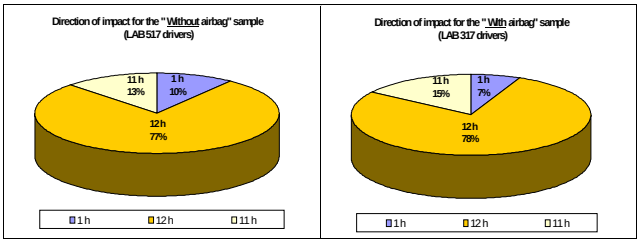

Figure 3

Because the distribution of our airbag cases essentially contains severe accidents, this study focuses on three speed classes for the following reasons:

- The risk of moderate to severe injuries is very low for EES < 36 km/h
- About 70% of the drivers/cars were involved in the range of EES 36-65 km/h.
- It is more likely that we can evaluate the positive effects of driver airbags in that range of crash violence.
- This speed range is centred on the crash severity of EuroNcap and European directive ECE 96/79…99/98 crash configurations.
- For EES above 65 km/h, the level of intrusion is often very high and thus the mortality is also high.

Figure 4 and 5 below show the sample distribution for both types of cars.

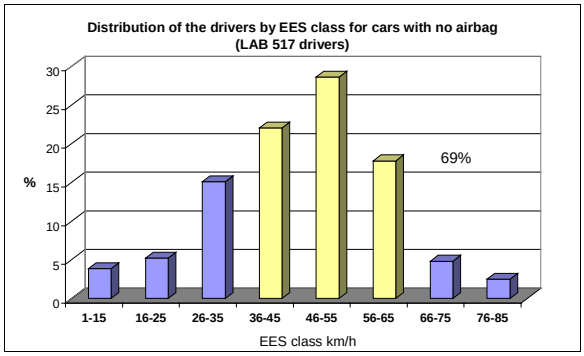

Figure 4

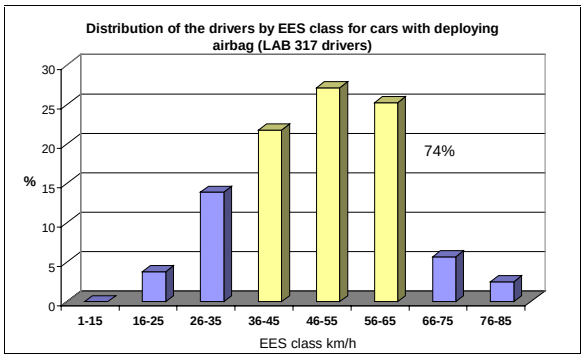

Figure 5

For these three selected EES classes, the remaining sample is respectively:

- Cars with driver airbag deployed = 235
- Cars with no airbag = 354

In France, persons killed during a road accident are very seldom post-mortem examined but fatalities with belt on can be observed in such severe crashes. Without airbag, for 16 killed among 20, no medical information was available. With airbag, no medical

report was available for 10 fatalities among 12 in this speed range.
It is therefore impossible to take them into account when making comparisons between injury distributions by body territories. Nevertheless it is interesting to examine the conditions of intrusion and age for these non-autopsied cases:

- With airbag, among the 10 drivers who were not post-mortem examined, 6 sustained an intrusion superior to 250 mm. The 4 other drivers were older than 65.
- Without airbag, among 16 non autopsied killed drivers :
  - 9 sustained an important intrusion
  - 3 cases were older than 65.
  - The 4 left cases sustained a full stiff frontal impact, 100% coverage, certainly having caused high level of deceleration.

The remaining sample of cars/drivers with injuries known is:
- Cars with driver airbag deployed = 225
- Cars with no airbag = 338

HEAD INJURIES:

Considering the AIS 3+ injuries as described in figure 6, only one driver has sustained such head injuries with a deployed airbag. This driver experienced a dashboard intrusion of about 400mm. The airbag efficiency in terms of severe injury reduction is obvious.

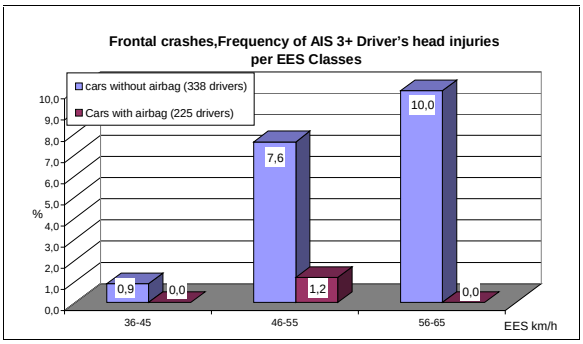

Figure 6

In the case of AIS2+ injuries with lower levels of injuries, like minor fractures and contusions, the effect is clear, especially for the higher EES class. There is actually a significant injury frequency decrease of about 82% in the range of 56 to 65 km/h. This is shown in figure 7

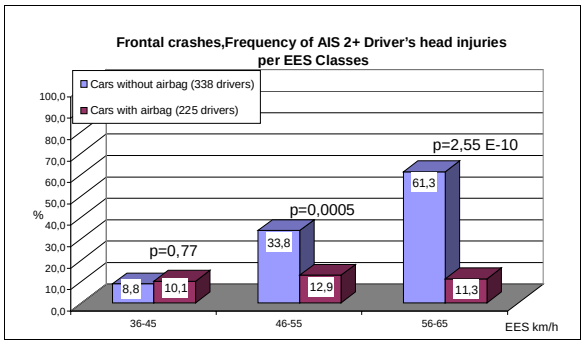

Figure 7

Looking at AIS 1+ injury frequency (figure 8), in this EES range, the airbag efficiency is also very significant, even in the higher speed class. Whereas for the non-airbag cases, injury frequency increases with the level of crash severity, one can see that the impact severity has no effect on the injury frequency with an airbag. The airbag has a sort of injury frequency limitation effect.

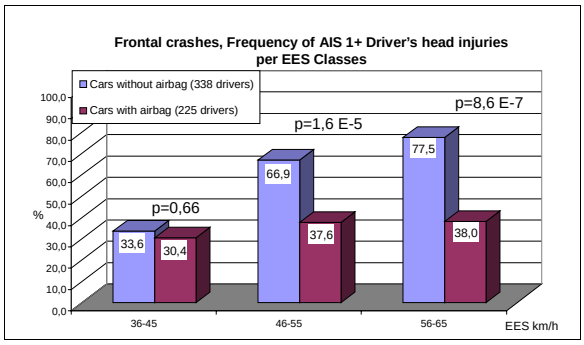

Figure 8

The following descriptions specifies the head lesions typology observed with and without airbag, for a same level of head AIS. Important differences are pointed out.

REMAINING LESIONS FOR HEAD AND FACE BY TYPE :

Cases with face fractures (teeth, nose, maxilla, and eye orbit) have been separated from other types of head lesions for various AIS levels.
In terms of very low level of injuries (AIS1), figure 9 shows that face fractures represent 25% of the lesions without airbag, even though only 7% remained with an airbag deploying. For a same level of AIS, this facial fractures frequency decrease is remarkable.

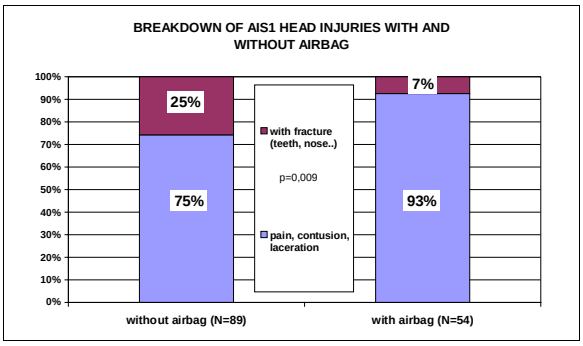

Figure 9

For AIS 2 injury level, difference must be made between short losses of consciousness and face fractures, whatever they are associated or not. In fact, these losses of consciousness, which have, in most of the cases, no medical consequences, represent more than 90% of the AIS 2+ injuries with airbag, as shown in figure 10.
Face fractures are observed for 50% of non-airbag cases, half of which being AIS 2 level. Here, again for a same AIS level, the head injury typology is very different.

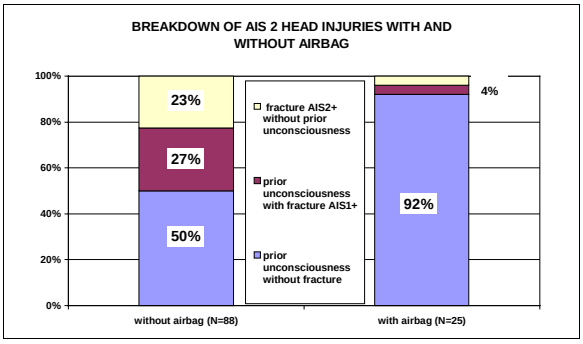

Figure 10

Considering AIS 3+, there's only one case in our database and the driver sustained a combination of face fractures and cerebral injuries.
Without airbag, we can observe that for 85% of 20 cases, these AIS 3+ lesions are attributable to important cerebral injuries associated with AIS 1+ fractures. AIS 3+ injury level comes from a complex face fracture only for 15% of the drivers. (Figure 11)

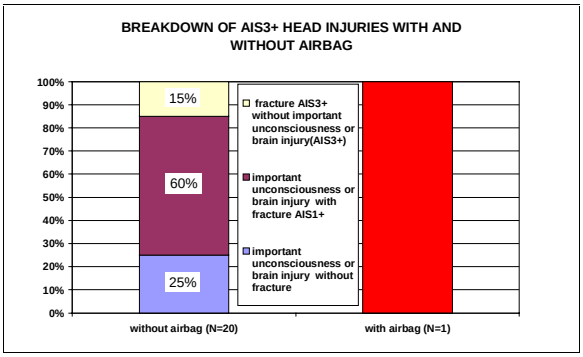

Figure 11

NECK INJURIES :

AIS 1 neck injuries are, as shown in figure 12, as frequent with airbag as without airbag for low speed crashes. This has been observed as well for AIS 1+ as for AIS 2+ head injuries, for this specific EES class.
But for higher speeds, figure 12 shows a significant risk reduction for this body part because of the airbag.

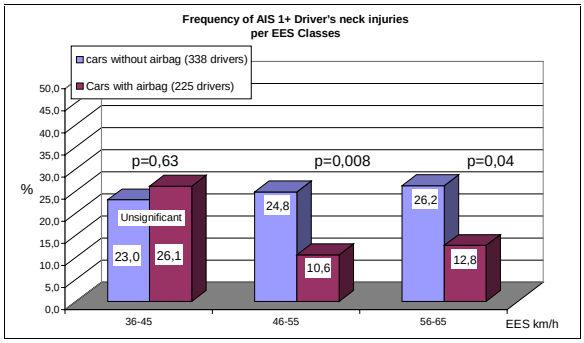

Figure 12

The AIS 2+ neck injuries frequency being so small, comparisons by EES classes would not be relevant. On the other hand, bringing together those three classes shows an injury risk reduction tendency, even though this difference is not yet statistically significant (p=0,16). We then get the following risks:

- Without airbag : 6/338 (that is to say 1.8%)
- With airbag : 1/225 (that is to say 0.4%)

UPPER LIMBS INJURIES:

Considering AIS 1+ upper limbs injuries all together, figure 13 tells us that, with or without airbag, no significant difference is observed.

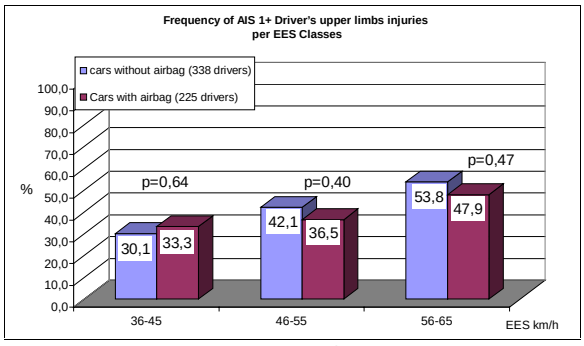

Figure 13

Figure 14 shows that for AIS 2+ injury level, for these crash severities, having an airbag deployed doesn't make the risk of fracture getting worse.

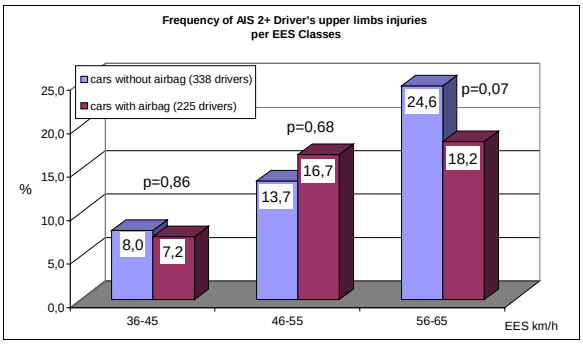

Figure 14

We know from Frampton's study (1) using CCIS cases that, among MAIS2+ with airbag, an increase of 54 % of these upper limbs AIS 2+ had been observed. The same method being applied to our 138 MAIS 2+ drivers sample, with airbag, doesn't show such a difference, the risk being quite identical.
In the US, Taylor (2) working on NAAS file, found an injury risk almost four times higher for AIS 2+ upper limbs risk, with airbag and belt, compared to belt only situation. These observations are certainly due to the US airbags that are noticeably bigger and more powerful than European ones. These US airbags also usually fire at lower speed levels.

INJURY RISKS FOR LOW SPEED CRASHES

In our sample we have a very few low speed crashes, just above the airbag-firing threshold, to check whether some additional AIS 1 injuries would occur in the airbag cases compared to non-airbag ones.
Despite this small sample size, it seems that there is no significant over risk of low level injuries on any of the three body areas studied. This is clear from figures 8, 12, 13 for EES 36-45 km/h. Anyway, even for the lower speed classes, below 35 km/h EES, no significant difference between airbag and non airbag were noticed maybe because the sample size.It is then very difficult to say if the airbag had a negative influence on the low level injuries at low speeds.
Anyway, the overall benefits obtained from high-speed airbag crashes are clearly positive, even if there were an additional risk of AIS 1+ from low severity impacts.

GLOBAL SEVERITY BY EES CLASSES

If we separate the above sub-sample in three EES classes, one can observe again a better global protection for the drivers having an airbag. This difference is more significant for the higher speed accidents.

Figure 15 describes this for the three EES classes separated with an indication of the probability of error. We can consider the difference "fairly significant" for the highest speed range (p= 0.11)

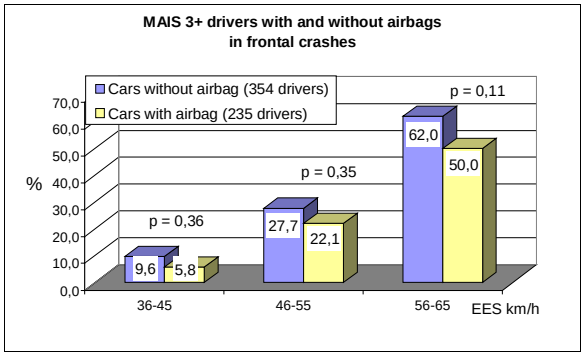

Figure 15

But is this global severity reduction by speed class only due to the airbag efficiency previously established? We can doubt this since these AIS 3+ head lesions are not the most frequent among severe injured drivers and are, as we'll see, often associated with other body area injuries.
Other factors like seat belts force limiters implementations can contribute to reduce this overall severity as discussed in the following paragraph for crashes between 36 and 65 km/h.

GLOBAL SEVERITY COMPARISON BETWEEN 36 TO 65 KM/H

Looking at the overall severity in terms of MAIS 3+ injuries for the two set of cars, a significant decrease can be observed from the non airbag to the airbag set of data (p=0,07). This is true for a sample compensated for the speed distribution bias.

	W/o Airbag (N=354)	With Airbag (N=235)
MAIS 3+ rate	**33 %**	**26 %**

Table 2
Global severity for drivers **(p = 0,07)**

26% of the drivers with airbag had a low-level force limiter (4 kN) with a specific fitted airbag since obviously none without airbag.
All these cars with 4kN limiters were removed from the sample in table 3. It indicates that the benefits from the airbag on the overall severity are low and that the difference is not really significant. This is probably closer to the actual situation.

	W/o Airbag (N=354)	With Airbag (N=173)
MAIS 3+ rate	**33%**	**30 %**

Table 3
Global severity for drivers without force limiter 4 kN **(p = 0,37)**

However, we believe that with more important numbers, a global efficiency, even low, could be observed from the only airbag influence all things being equal

Actually, if we analyse in details the 94 MAIS 3+ drivers without any airbag nor force limiters from this last table, only 21% have sustained AIS 3+ head injuries, a third of which being isolated lesion. Airbag efficiency, in terms of AIS 3+ head injury reduction, therefore in terms of global severity, can only be applied to these remaining cases. Given this, the MAIS 3 frequency reduction because of the airbag is about 7%. This is approximately what we found in table 3, a 3 point reduction that is to say an efficiency of about 10 %. The sample must be much more numerous to provide a statistically significant global severity reduction.

CONCLUSION

This study shows that, in a range of severe frontal crashes, airbags are extremely efficient in terms of head and face severe injury risk reduction. Moreover, no additional low or moderate AIS 2+ injuries are generated to other body areas like neck or upper limbs.
Furthermore, for a same level of head AIS, the injury typology is very different and the almost complete facial fractures reduction must be stressed.
Considering low speed crashes, more work is requested on a bigger sample size with more low severity frontal impacts to see whether the airbags could present a negative balance for AIS 1.
As a first conclusion, this study shows that airbag is very efficient in severe frontal crashes, without associated increase of the severe injury risk at lower speeds.
In terms of global severity reduction, this can be estimated about 10%

REFERENCES

1. “Effectiveness of Airbag Restraints in Frontal Crashes- What European Field Studies tell us”, R. Frampton and al, IRCOBI , September 2000, Montpellier,

2. “Detecting Arm Trauma from a Deploying Driver Air Bag", Lynne M. Taylor and al, 23 rd International Workshop on Human Subjects for Biomechanical Research,